

REMARKS

Applicants thank the Examiner for the courtesy extended to Applicants' attorney during the interview held March 9, 2004, in the above-identified application. During the interview, Applicants' attorney explained the presently-claimed invention and why it is patentable over the applied prior art. The discussion is summarized and expanded upon below.

The rejection of Claims 1-4, 7, 8, 12, and 14-16 under 35 U.S.C. § 102(b) as anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over, U.S. 5,424,256 (Yoshimura et al '256) or U.S. 5,369,065 (Yoshimura et al '065), is respectfully traversed. (The term "Yoshimura et al" is used below when applicable to either Yoshimura et al '256 or Yoshimura et al '065).

As recited in Claim 1, the invention is a wear resistant member, comprising:

a ball member consisting essentially of a silicon nitride sintered body;

wherein the silicon nitride sintered body comprises from 75 to 97% by mass of silicon nitride, from 0.2 to 5% by mass of particles of titanium nitride and from 2 to 20% by mass of a grain boundary phase comprising a Si-R-Al-O-N compound, where R is a rare earth element;

wherein the particles of titanium nitride have a long axis of 0.04 μm or more and 1 μm or less, and at least 80% by volume of the particles of titanium nitride have an aspect ratio in the range of from 1.0 to 1.2,

wherein the ball member has a rolling fatigue life of 400 hr or more when tested with a thrust bearing testing machine, under the conditions of opponent material of a SUJ2 steel plane table provided by JIS G4805, a maximum contact stress of 5.9 GPa, a ball, and a number of rotation of 1200 rpm, and the rolling fatigue life is measured until a surface of the ball member is peeled off.

The present invention relates to a wear resistant, ball member consisting essentially of a silicon nitride excellent in sliding characteristics, in particular rolling fatigue life. The titanium nitride particles exist mainly in the grain boundary phase of the silicon nitride sintered body, thereby reinforcing the grain boundary phase to contribute to an improvement in sliding characteristics, in particular rolling fatigue life of the silicon nitride sintered body.

However, when the particle diameter of the titanium nitride particles is large, or the titanium nitride particles have a distorted form, the sliding characteristics of the silicon nitride sintered body decline. In particular, the form of the titanium nitride particles affects the rolling fatigue life of the silicon nitride sintered body.

The ball-shaped wear resistant member of the present invention has a rolling fatigue life of 400 hr or more. Such an excellent rolling fatigue life is based on the titanium nitride particles having a long axis in the range from 0.04 to 1 μm and an aspect ratio in the range from 1.0 to 1.2 (at least 80% by volume of particles), and $\beta\text{-Si}_3\text{N}_4$ phase as a main phase of the silicon nitride sintered body.

When the long axis of the titanium nitride particles exceeds 1 μm , the sliding characteristics of the silicon nitride sintered body deteriorate. But the sliding characteristics cannot be improved if the long axis of the titanium nitride particles is too small. As shown in Tables 4 and 5 of the specification, the titanium nitride particles having a long axis in the range of from 0.04 to 1 μm contribute to improvement of the sliding characteristics.

Furthermore, at least 80% by volume of the titanium nitride particles have an aspect ratio in the range of from 1.0 to 1.2. The aspect ratio defines a ratio of long axis to short axis. When the ratio of slim particles of which aspect ratio is more than 1.2 exceeds 20% by volume, anisotropy and fluctuation in the reinforcement of the grain boundary phase occur. Thereby, the rolling fatigue life of the silicon nitride sintered body deteriorates.

When the titanium nitride particles have an aspect ratio in the range of from 1.0 to 1.2, the grain boundary phase can be uniformly reinforced and sliding shock can be effectively relieved. Therefore, the sliding performance such as rolling fatigue life can be markedly improved.

It is clear that the silicon nitride sintered body in the present invention has a β - Si_3N_4 phase, because the silicon nitride sintered body is made by sintering at a temperature in the range from 1600 to 1900°C, as recited in non-elected Claim 17. At such a range, the silicon nitride raw material powder becomes the β - Si_3N_4 phase.

A silicon nitride sintered body comprising β - Si_3N_4 phase is excellent in sliding characteristics. Furthermore, the silicon nitride sintered body comprises titanium nitride particles existing in the grain boundary phase. With titanium nitride particles having a long axis in the range from 0.04 to 1 μm and an aspect ratio in the range from 1.0 to 1.2, the grain boundary phase can be uniformly reinforced, and sliding shock can be effectively relieved.

Therefore, the rolling fatigue life of the ball-shaped wear resistant member can be markedly improved. That is, the ball-shaped wear resistant member in the present invention has a rolling fatigue life of 400 hr or more. With such a ball-shaped wear resistant member, a rolling bearing member having a long life can be realized.

Yoshimura et al '256 discloses a silicon nitride sintered body consisting of prismatic crystal grains of Si_3N_4 and/or sialon, equi-axed crystal grains of Si_3N_4 and/or sialon, a grain boundary phase existing among these prismatic and equi-axed crystal grains and particles dispersed in the grain boundary phase, in which the prismatic crystal grains have an average grain size of 0.3 μm or less in their minor axis, and an average grain size of 5 μm or less in their major axis, and the equi-axed crystal grains have an average grain size of 0.5 μm or less and the dispersed particles have an average particle size of 0.1 μm or less, the volume of the dispersed particles being 0.05% by volume or more on the basis of the total volume of the

rest of the sintered body (column 2, lines 34-48). The prismatic crystal grains are β -crystals and the equi-axed crystal grains are α -crystals (column 3, lines 28-29). Yoshimura et al '256 discloses further that the dispersed particles are preferably of titanium compounds, such as TiN (column 4, lines 13-19), and TiN having an average particle size of 0.1 μm or less are described (column 4, lines 64-66). Yoshimura et al '256 is mainly concerned with the strength of silicon nitride sintered bodies, such as for use in frictionally sliding parts (column 1, line 11 ff).

Yoshimura et al '065 discloses a silicon nitride sintered body constituted by a matrix phase consisting of 60-99% by volume β - Si_3N_4 and/or β' sialon with the balance being α - Si_3N_4 and/or α' -sialon, wherein the β - Si_3N_4 and/or β' -sialon consists of hexagonal rod-like grains having a diameter of 500 nm or less in the minor axis, and an aspect ratio of 5 to 25 and the α - Si_3N_4 and/or α' -sialon consists of equi-axed grains having an average diameter of 300 nm or less, and titanium compounds are contained within the grains of the matrix phase and a grain boundary phase (column 2, lines 17-30). The titanium compounds consist mainly of nitride compounds, such as titanium nitride (column 3, lines 23-26), which compounds are "fine particles of the order of nanometer" (column 3, lines 34-35). Yoshimura et al '065 further discloses that the average particle size of the titanium compounds that are dispersed in the matrix crystal grains is preferably from 1 to 100 nm and the average size of those that are dispersed in the grain boundary phase is preferably in the range of 300 nm or less (paragraph bridging columns 3 and 4). Yoshimura et al '065 is concerned with silicon nitride sintered bodies superior in both strength and fracture toughness (column 9, lines 31-36).

Yoshimura et al neither disclose nor suggest the presently-claimed invention. Neither reference discloses or suggests a ball-shaped silicon nitride sintered body. Nor would it be expected that the silicon nitride sintered bodies of Yoshimura et al meet the rolling fatigue life limitations of the present claims. As the Komatsu Declaration shows, the presence of α -

Si₃N₄ phase acts to lower the rolling fatigue life to a time below the presently-recited minimum of 400 hr. Note that Yoshimura et al require the presence of both α -Si₃N₄ and β -Si₃N₄. Nor do Yoshimura et al disclose or suggest that at least 80% by volume of their titanium nitride particles have an aspect ratio in the range of from 1.0 to 1.2, as recited in Claim 1, or that the particles of titanium nitride have a long axis of 0.04 μ m or more and 1 μ m or less, as also recited in Claim 1. The significance of these limitations are reflected in the comparative data in the specification wherein Table 2 at page 33 shows the influence of the structural limitations and physical properties for Embodiment 2, which is according to the presently-claimed invention, and Comparative Examples 4-6, which are for purposes of comparison.

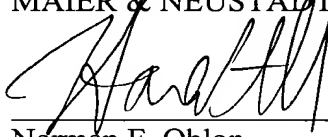
Clearly, one could not have predicted the above-discussed comparative data in the specification and in the Komatsu Declaration from the disclosures in Yoshimura et al.

For all the above reasons, it is respectfully requested that the above rejections be withdrawn.

All of the presently pending claims in this application are now believed to be in immediate condition for allowance. Accordingly, the Examiner is respectfully requested to pass this application to issue.

Respectfully submitted,

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